NSFA WG Update

WG Numerical Standards of Fundamental Astronomy

- Goals
  - Update “IAU Current Best Estimates”
  - Conforming with IAU Resolutions/IERS Conventions/SI
- Members

N. Capitaine
A. Fienga
W. Folkner
T. Fukushima
J. Hilton
C. Hohenkerk
G. Krasinsky
B. Luzum
G. Petit
E. Pitjeva
M. Soffel
P. Wallace

IAU 2009 Resolution B2

- Adopted at the 2009 IAU General Assembly
- Current Best Estimates (CBEs) of WG became the IAU (2009) System of Astronomical Constants
- Recommends
  - Keeping CBEs as an electronic document
  - Developing a procedure for adopting CBEs
  - That IAU Division I establish a permanent body to maintain CBEs for fundamental astronomy

Features of New System wrt 1976 IAU System

- New, more descriptive category names
- Eight constants added: L_B, TDB_0, θ_0, $d\theta/dt$, M_S/M_{Eris}, M_{Ceres}/M_S, M_{Pallas}/M_S, M_{Vesta}/M_S
- Two constants removed: τ and p
- Twelve values have been replaced: G, au, L_C, M_M/M_E, M_S/M_V, M_S/M_{Ma}, M_S/M_J, M_S/M_{Sa}, M_S/M_P, GM_S, GM_E, ε_0

Explanation of Table

- Items listed in green are new additions to the list of constants
- Unless otherwise noted, the constants should be considered to be in terms of SI units

Defining Constants (SI)

Constant	Value	Reference	Adopted
Natural Defining Constants			
c	2.997 924 58 x 10^{8} ms^{-1}	CODATA 2006	IAU, IERS
Auxiliary Defining Constants			
k[1]	1.720 209 895 x 10^{-2}	IAU 1976, Gauss (1857)	IAU
L_G	6.969 290 134 x 10^{-10}	IAU 2000 Res. B1.9, Petit (2000)	IAU, IERS
L_B	1.550 519 768 x 10^{-8}	IAU 2006 Res. B3	IAU
TDB_0[2]	-6.55 x 10^{-5} s	IAU 2006 Res. B3	IAU
θ_0[3]	0.779 057 273 264 0 revolutions	IAU 2000 Res. B1.8, Capitaine *et al.* (2000)	IAU
$d\theta/dt$[3]	1.002 737 811 911 354 48 rev UT1 day^{-1}	IAU 2000 Res. B1.8	IAU

Current Best Estimates (SI)

Constant	Value	Reference	Adopted
Natural Measurable Constants			
G	$6.674\ 28(67) \times 10^{-11}\ m^3 kg^{-1} s^{-2}$	CODATA 2006	
Derived Constants			
au[4]	$1.495\ 978\ 707\ 00(3) \times 10^{11}$ m	Pitjeva and Standish (2009)	
L_C	$1.480\ 826\ 867\ 41(200) \times 10^{-8}$	Irwin and Fukushima (1999)	IAU, IERS

Current Best Estimates (SI)

Constant	Value	Reference	Adopted
Body Constants[5]			
M_M/M_E	1.230 003 71(4) x 10^{-2}	Pitjeva and Standish 2009	
M_S/M_{Me}	6.023 6(3) x 10^6	Anderson et al. (1987)	IERS
M_S/M_V	4.085 237 19(8) x 10^5	Konopliv *et al.* (1999)	
M_S/M_{Ma}	3.098 703 59(2) x 10^6	Konopliv *et al.* (2006)	
M_S/M_J	1.047 348 644(17) x 10^3	Jacobson *et al.* (2000)	
M_S/M_{Sa}	3.497 901 8(1) x 10^3	Jacobson *et al.* (2006)	

Current Best Estimates (SI)

Constant	Value	Reference	Adopted
Body Constants			
M_S/M_U	2.290 298(3) x 10^4	Jacobson *et al.* (1992)	IERS
M_S/M_N	1.941 226(3) x 10^4	Jacobson (2009)	
M_S/M_P	1.365 66(28) x 10^8	Tholen *et al.* (2008)	
M_S/M_{Eris}	1.191(14) x 10^8	Brown and Schaller (2007)	
M_{Ceres}/M_S	4.72(3) x 10^{-10}	Pitjeva and Standish (2009)	
M_{Pallas}/M_S	1.03(3) x 10^{-10}	Pitjeva and Standish (2009)	

Current Best Estimates (SI)

Constant	Value	Reference	Adopted
Body Constants			
a_E [6]	6.378 136 6(1) x 10^6 m	Groten (2000), Bursa *et al.* (1998)	IERS
J_2 [6]	1.082 635 9(1) x 10^{-3}	Groten (2000)	IERS
dJ_2/dt	-3.001(600) x 10^{-9} cy^{-1}	IAU 2006 Res. B1, Capitaine et al. (2005)	
GM_S	1.327 124 420 99(10) x 10^{20} m^3s^{-2} (TCB-compatible) 1.327 124 400 41(10) x 10^{20} m^3s^{-2} (TDB-compatible)	Folkner *et al.* (2008)	
GM_E	3.986 004 418(8) x 10^{14} m^3s^{-2} (TCB-compatible) 3.986 004 415(8) x 10^{14}	Ries *et al.* (1992)	IERS

Current Best Estimates (SI)

Constant	Value	Reference	Adopted
Body Constants			
W_0	6.263 685 60(5) x 10^7 m^2s^{-2}	Groten (2000)	IERS
ω[7]	7.292 115 x 10^{-5} rad s^{-1}	Groten (2000)	IERS
Initial Value at J2000.0			
ε_0 [8]	8.438 140 6(1) x 10^4 ''	IAU 2006 Res. B1, Chapront *et al.* (2002)	IAU

Notes

1. The Gaussian gravitational constant, k, defines au.
2. This constant comes from the expression TDB = TCB – $L_B \times (JD_{TCB} - T_0) \times 86400 + TDB_0$.
3. This constant comes from the expression θ(UT1) = 2π(0.7790572732640+1.00273781191135448 $\times$ (Julian UT1 date – 2451545.0).
4. The value for au is TDB-compatible. An accepted definition for the TCB-compatible value of au is still under discussion.
5. All values of the masses from Mars to Eris are the sum of the masses of the celestial body and its satellite(s).

Notes

6. The values for a_e and J_2 are “zero tide” values (see IERS Conventions for an explanation of the terminology). Values according to other conventions can be found in Groten (2000).
7. ω is a nominal value and was chosen to have the number of significant digits limited to those for which the value can be considered constant.
8. ε_0 is a component of the IAU 2006 precession model, which includes expressions that are time dependent.
9. The rate of precession appearing in previous lists of constants is no longer appropriate given the IAU 2006 precession model.

Report

- In preparation
- To be published in *Celest. Mech. Dyn. Astr.*

General Scientific Issues

- Keep up with improvements of CBEs due to improved measurements, space missions, etc.
- Deal with expected limitation of constants
- Alternative methods for determining masses of asteroids
- Values provided by the geodetic community

Specific Scientific Issues (2009-2012)

- New values for the mass of Mercury
  - Based on MESSENGER data

Specific Scientific Issues (2009-2012)

- TCB-compatible au
  - Currently there is no accepted definition for a TCB-compatible au
  - Linked to the current definition of au
    - Would be impacted by a change in definition
  - Concern of Commission 52

Specific Scientific Issues (2009-2012)

- Gaussian gravitational constant (k) / astronomical unit (au) / heliocentric gravitational constant (GM_S)
  - Currently k is defining constant and au is a measured constant
    - Provided by K. Gauss in 19th century
  - Proposal by Capitaine (among others) to make au defining constant

Keep k a defining constant

- Pros
  - Currently accepted practice
  - Long-standing definition
  - May be difficult to re-define practically
- Cons
  - Value is not modern

Make au a defining constant

- Pros
  - Fixes au, which matches many astronomers' expectations
- Cons
  - Not currently accepted practice
  - Can all software handle the change?

Functionality Issues (2009-2012)

- How to adopt future CBEs?
  - Need to document a formal procedure
    - Request/proposal
    - Discussion
    - Vote
      - Plurality, Simple majority, Supermajority, Consensus
    - Archive old CBEs
    - Modify CBEs
  - Discuss draft of procedure at Journees

Functionality Issues (2009-2012)

- Design of CBE web site
  - Where is it hosted?
    - IAU or Division I Site
    - Local Site
  - Functionality
    - Based on similar ideas?
      - Gaia constant’s web site
        - » http://gaia.esac.esa.int/gpdb/

Functionality Issues (> 2012)

- Future of group
  - To be decided by IAU Executive Committee
  - IAU Division I proposing that the IAU by-laws be changed to allow standing working groups
    - NSFA WG could become a standing working group